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ABSTRACT

An experimental computer-assisted instructional (CAI) system is described. The first segment of the report discusses some basic considerations in the design of the system in which as many features as possible of a large-scale CAI system were implemented on a minicomputer. Aspects of the system which are elaborated upon include the PDP-11 computer and its peripherals, the key reader system and learning environment, the system input and output, the student record, the test file, the course definition language, the student progress report and input generation. Part two of the report describes two simulated multi-media courses in order to demonstrate the decisions which go into planning a course and to show how the course is utilized. (Author/PB)

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# SIMULATING CMI ON A MINI-COMPUTER

By

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November 1973

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A prototype computer based instructional system has been developed to demonstrate a computer managed learning environment. In addition to its capabilities for managing, monitoring, and delivering individualized instruction as part of a multi-media instructional system, the system provides the mechanism for experimentally examining hypotheses, i.e., instructional strategies and media preference. This guide to the use of the CMI describes the hardware configurations, some of which were developed and interfaced under other tasks performed under the same contract, and the software packages written to operate the hardware and to develop course material for computer based delivery. Sample report sheets are included to demonstrate the monitoring capabilities of the system. Two courses are described to show how lesson materials are prescribed to accommodate individual

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differences in aptitude, motivation, progress, and preference, and the ways in which student progress can be measured by instructors and authors of course and test material.

## SUMMARY

### Problem

The objective of this program was to design and develop mini-computer based instructional system to investigate a computer managed learning environment for Air Force technical training.

### Approach

The basic design approach for the system was to implement as many features of large scale CMI system as possible, considering the limited storage capacity of a mini-computer. Technical training course materials were modified to provide a realistic demonstration of the system capabilities.

### Results

Hardware interfaces were developed for student key-readers, an interactive graphic terminal, a test form reader, and a computer controlled slide projector. The CMI system also incorporates the manufacturer's hardware such as the CRT terminal, the card reader, and the line printer.

A series of key-reader devices, capable of reading data from a coded key, will identify the user and his location to the CMI system. The key-reader system is used to monitor the utilization of instructional materials and media devices not directly controlled by the computer.

Computer software was developed to operate all of the hardware. A series of short lessons was prepared to show how an instructional course could be managed using a simple adaptive model with pretests, lesson options based on student characteristics, course tests, and feedback for the student or instructor.

### Conclusions

The experimental system has provided insight to the many contingencies of hardware/software interfacing, hardware reliability, media selection, and presentation of course material. Transfer of this information to the design and implementation of larger systems will provide the Air Force and the educational community in general with a training system that is capable of utilizing the full potential of instructional and computer technology.

## PREFACE

This final report was submitted by the Denver Research Institute, University of Denver, under Contract No. F41609-72-C-0005, Project Number 1121, Task Number 01, Work Unit 04, with the Technical Training Division, Air Force Human Resources Laboratory, Lowry Air Force Base, Colorado 80230. Dr. Anita S. West was the Principal Investigator and Ms. Sandra Bleistein was the Task Leader. Kenneth C. Wasmundt assisted with the programming. The research reported on here was conducted from December 1971 to May 1973 in support of Technical Training Division Project 1121, Task 02, Work Unit 03.

The authors wish to acknowledge the guidance and support of the Project Scientist, Mr. Joseph Yasutake; and the Task Scientist, Mr. Gerald S. Walker. Acknowledgement is also made to Capt Edward M. Gardner and Mr. L. R. Espelands for their cooperation and support.

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## INTRODUCTION

### Background

Computer managed instruction (CMI) is the result of new computer technology applied in the field of education. Basic to the concept of CMI is the emphasis on "individualized instruction," which takes into account the great diversity of background, goals, and proficiencies of the users. The computer is programmed to keep track of a student progressing at his own pace and to make the necessary decisions for the curriculum to be tailor-made to the student's own level and learning aptitudes. The computer is required to manage the curriculum by allocating learning resources, maintaining progress records, administering and scoring tests, and providing access to files of student information for reference by instructors. In addition, the computer assists with instruction (CAI) by providing direct interaction between the student and the material to be learned.

### Purpose

The AFHRL Computer Managed Instructional System, CMI, developed under contract with Denver Research Institute (DRI), is a small prototype computer managed instructional system, written for the DEC PDP-11 computer and its peripherals.

The development of this system was motivated by the following needs:

- As part of the "Advanced Instructional System" (AIS). AIS is a large scale computer managed instructional system, expected to be operational at Lowry Air Force Base within the next four years.
- To allow for experimentation with training research hypotheses, instructional materials and media selection. For example, to test hypotheses involving presentations of instructional media to students as a function of content, of proficiency tests, stated preferences, and past performance.
- To demonstrate computer managed and computer assisted instruction.
- To familiarize instructor personnel with a mode of instruction to become more prevalent in the future. This familiarization is expected to lead to instructor authorship of CMI materials as well as to acquaint him with his changing role in the instructional process.

### Objectives and Development

One of the main objectives in the design of the system was to implement as many features of a large scale CMI system as possible, given the limited storage capabilities of a mini-computer. This was partly done by reserving demonstrative use of the computer for instruction only when it was the best method of presentation and by utilizing programmed texts, microfiche, films and slides, wherever appropriate, as a fully operational CMI system might do.

The system was developed in three phases. The first phase, design of the system, is outlined below:

- Design of CMI systems files, including:
  a. consideration of student record items,
  b. test definition records and statistics,
  c. course definition language elements and capabilities.

- Design of programs to generate the above files in interactive and batch modes.
- Design of the CMI operating system and its capabilities.
- Design of the system output and reporting capabilities.

During the next phase, the implementation of the necessary computer programs was completed.

The last phase entailed design and development of courses for demonstrations. These were designed to demonstrate the use of instructional materials, branching strategies, audio/visual presentations, and reinforcement and remedial procedures.

### Limitations

Although the CMI system has the capability of keeping track of all active students at the various learning stations as well as scoring and recording test results at the optical reader station, it is capable of interacting with only one student at a time at the display terminal and keyboard. That is, it is not a true time sharing system. Further, the total number of students, with records maintained on line, and the maximum size of a course are limited by the available disk storage. Therefore, while many of the features of a time sharing system are demonstrable utilizing the CMI, its use as a teaching device is restricted by these limitations.

### Organization of this Report

There are two major segments to this report. The first discusses some basic considerations in the design of this CMI system and elaborates on its features. The second segment describes simulated multi-media course offerings developed under this system in order to demonstrate how the system is utilized and the decisions that go into planning a course.

## DISCUSSION

### The Computer and Its Peripherals

The CMI system was developed for a DEC PDP-11 computer with a 24K word memory, two DECtape drives, and one disk drive. (An additional disk drive will be added to this configuration in the near future and will help to improve computer response time.)

The student interfaces with the CMI system at a VT05 CRT (cathode ray tube) display terminal. The terminal includes a visual display for verbal data, and the student may communicate with the programmed curriculum material by typing on a keyboard. Adjacent to the CMI is a double slide screen (associated with two computer controlled slide carousels) for presenting still images to the student.

**Figure 1. VT05 Display Terminal**

A Bell and Howell optical mark reader is available to the user for entering test answers on a marked card form. Tests may be assigned by the CMI system to be taken off-line. A line printer returns the scored test results to the student at the optical reader. In addition, the line printer is utilized by the CMI system to generate lesson prescriptions for the student as well as to output report files on student progress and the current status of student records and test files upon inquiry.

**The Key Reader System and Learning Environment**

One of the unique features of the DRI/CMI system is the *key reader system*. The key reader is utilized by the CMI system to keep track of learning resources and to compute the time spent on each assignment.

One portion of the key reader system consists of up to 31 "key reader boxes" with unique station identification codes, interfaced to the computer via a DR11A interface. The key reader boxes are stationed at various learning carrels. For example, key reader #0 is at a visual display terminal; key reader #1 is at an optical reader/line printer station; key reader #3 is at a sound/slide carrel; key reader #5 is at a microfiche carrel; and key readers #2 and #4 are at reading carrels to be used for programmed instruction and other text-utilizing assignments.

**Figure 2. Key Reader**

The other part of the key reader system is a set of plastic coded keys. Each user participating in a CMI course is given a coded plastic key. The key code then becomes a unique identification number for him. The keys are prepared in different colors to help users identify their own.

Before a student begins his course, he must key in at key reader station #0, the visual display terminal. The computer reads the key identification and fetches the associated student record from the disk. The CMI system determines the student's current status in the curriculum (from his record file) and proceeds with the course. The student may be given an assignment to one of the off-line learning carrels; on

the other hand, he might receive computer assisted instruction and an associated slide presentation at the visual display station. When the student receives an assignment at another learning station, he keys out of key reader #0. The CMI system records the time spent at station #0 in a report file and adds the elapsed time onto his current lesson time account.

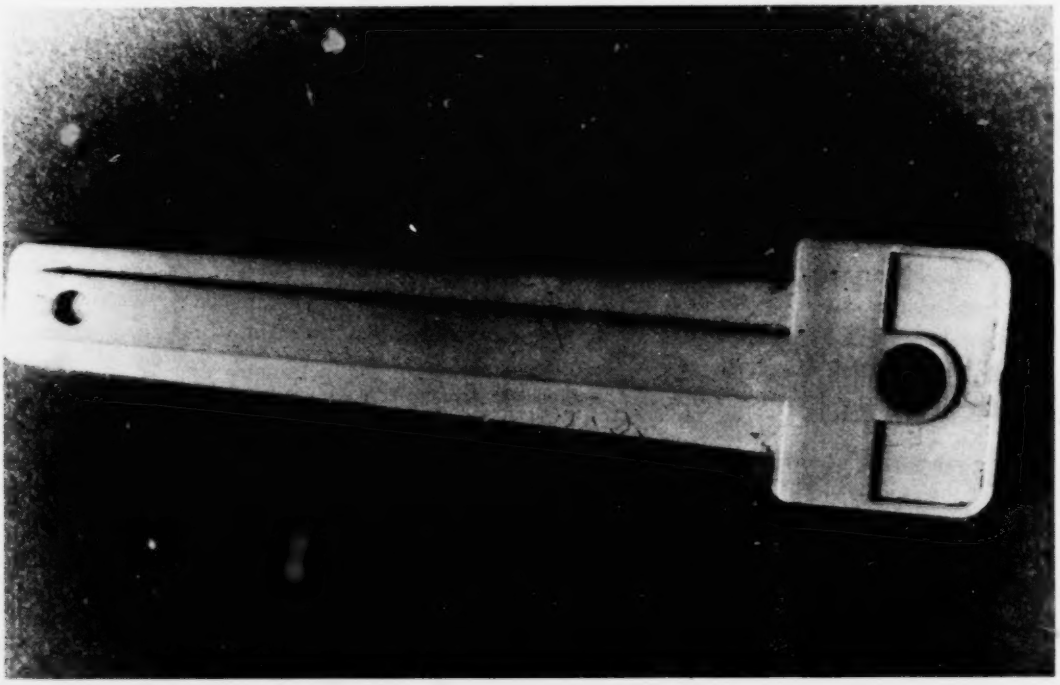

**Figure 3. Plastic Key**

Each key reader box has a small red light on its front panel and this light remains on during use. If a student keys into a key reader station that was not assignd to him, the CMI system will reject him by turning off the light. The student may then return to the display terminal where he will be redirected to his assigned station.

When a student keys into any assigned key reader station, the CMI system will keep an account of the time spent there, record it in his student record and print it in his progress report. These reports are accessible to the instructor as well as to the author of the material who can use this feedback to modify the course.

### The Design of System Input and Output

The specifications for design of system input and output were the first steps in the development of the CMI since these specifications ultimately determined the entire capability of the system. A major consideration was to define a student record (under the limited available disk storage circumstance) that would adequately reflect the student's level, proficiencies and background, while producing and retaining a current history of his progress and performance in a course. The specifications for design of the test files were determined by the assortment of testing modes and situations envisioned

and the required capabilities for analysis of the results. The development of "course writing" language elements defined the complexity of branching strategies and interactions with the student. The discussion below deals with these three system inputs as well as the student progress report system output.

## THE STUDENT RECORD

The initial information in the student record consists of student identification data and background information such as aptitude and attitude test scores, previous courses taken, current level and goal. Furthermore, it contains curriculum associated information such as the course name and performance model in the course. The CMI system provides dynamic record-keeping, adding an account of the student's paths and progress, the time spent on each assignment and periodic test grade reports. It is the role of the computer to utilize these parameters (found in the student record) in order to match the available learning resources to the individual student.

The student record consists of two contiguous, 64-word blocks on disk. The first block contains general information relating to the student and course. The second block is partitioned into eight 8-word segments where each segment contains information associated with the student's activity in a lesson module of the course. (A course may be partitioned into a maximum of eight lesson segments.) A detailed summary of student record items is contained in Appendix A.

The student identification information includes his name and key code. The CMI system always addresses the student by his first name, however for the purpose of accurate identification, the student progress report is headed by his entire name (last, first and middle initial) as well as his key code. The key code is used by the system to associate the appropriate student record with the active student keying in at a learning station.

The student's background is represented in his record by indications of his current level, his goal, and previous experience with CMI. In addition, there are six fields available for holding input data such as aptitude and attitude test scores or other psychological indices pertinent to selecting appropriate branching strategies in the assignment of instructional alternatives within the curriculum. For example, trait anxiety, response latency patterns or pretest scores might be relevant to the decision making processes of a course.

Curriculum-associated data relates to the specific course in which the student is enrolled. The course name is used to fetch the appropriate course (from the disk) when an active student keys into a learning station. A performance model for the course is contained in the student record in the form of performance times and achievement test scores for each lesson module. This model may be that of an average student, of an "expert" or advanced student, or perhaps a minimum performance criterion in the course. The CMI system computes a time and achievement ratio of the student's performance relative to the model. These ratios are an aspect of the student's profile within the course and are utilized by the CMI to indicate student progress, to reflect the need for remedial procedures and to project completion times.

The CMI system does dynamic record keeping by storing information reflecting the student's progress, performance, and current assignment (e.g. his current learning station or test assignment).

The current lesson number indicates the student's status in the course and is utilized by the CMI system when storing specific lesson-associated information in the student record. This information

includes learning parameters such as the rate at which a student moves through the course material, record of the instructional medium assigned to a lesson (e.g. sound-slide, computer-assisted instruction), the student rated difficulty of the lesson module and achievement test scores for the lesson.

Additional fields in the student record include three "switch" fields that may be accessed and utilized by a CMI course. For example, they may be used as accumulators to compute complex functions of the various learning parameters for the purpose of branching strategy. They may be used as counters to record the number of student "retries" for success at a given task or simply to remember information that needs to be recalled at some future point in the curriculum. The information stored in these fields is accessible only to the CMI system and cannot be obtained upon inquiry. All of the other fields in the student record described above are accessible to both the CMI system and to instructor personnel upon inquiry. In particular, all of the lesson-associated items are accessible by the CMI system and may be utilized for storing data other than was intended for that field. For example, response latencies may be generated and retained in unused test score fields.

```
NAME= STATISTICS       ,RED                    KEYID=0137
AGEA= 0000  AGEE= 0000  ATT = 0000
AGER= 0000  AGEM= 0000  AFQT= 0065  TRATIO= 0.95  ARATIO= 1.08
00 PREVIOUS COURSES C          C     .    C     .
STATUS=0  NSCR=0000  STATION=00  KEY OUT  LESSON=5  LOGOFF=01 ERR=0000
COURSE NAME CSTAT ,AIS  LEVEL:01 GOAL 01   LESSONS=5
LESSON   START DATE                  TEST #
  MEDIA       FINISH DATE
    STATUS                TIME              SCORES
      DIFFICULTY          AVG    ACT.     AVG TOT  1   2   3   4   5   6
1 0  2  3  03162 03162 000.25 000.33 003 070 070 075 067 000 000 000 000
2 0  2  0  03162 03162 000.13 000.10 000 065 075 000 000 000 000 000 000
3 0  2  0  03162 03162 000.15 000.13 000 000 000 000 000 000 000 000 000
4 0  2  0  03162 03162 000.20 000.13 004 075 082 050 100 100 000 000 000
5 0  2  0  03162 03162 000.00 000.03 005 000 054 100 000 100 000 000 000
6 0  0  0  00000 00000 000.00 000.00 000 000 000 000 000 000 000 000 000
7 0  0  0  00000 00000 000.00 000.00 000 000 000 000 000 000 000 000 000
8 0  2  2  03162 03162 000.95 001.08 000 100 000 000 000 000 000 000 000
COURSE FILE TOTAL TIME= 00.73          AVG=210
```

**Figure 4. Sample Student Record**

## THE TEST FILE

Implicit in the use of CMI is the utilization of the computer to conveniently administer and score achievement tests. Individuals may be tested simultaneously by the same or different tests, with provision for allowing each subject to answer questions at his own speed. The CMI system can administer tests in two ways. It can design and deliver a different test for each subject from a pool of precalibrated test items imbedded in the curriculum material or assign an appropriate test from a file of predefined tests. The first method (items imbedded in the curriculum material) facilitates offering remedial procedures and hints upon receiving incorrect responses and can incorporate the number of student retries required for success into the scoring procedure. Thus a history of gradations of right and wrong, of interest in tracking cognitive processes, is acquired. On the other hand, the CMI system may choose to assign an appropriate test from a pool of predefined tests available in the test file. This section will discuss the features of the test file system.

The CMI test file system allows a maximum of 50 test items per test. Tests to be taken off-line are constrained to a 40 item maximum because of the limiting size of the marked card test answer form. The marked card test answer form may be used for true/false and multiple-choice (A-E) test items. An additional test format is provided for tests taken at the display terminal (on-line tests). Questions requiring numerical or one word responses containing less than ten characters may be administered through on-line testing procedures.

A useful feature of the test file is the provision for assignment of a category code to each test item. Up to six categories may be utilized by the author in the test structure design. When scoring a test, the CMI system will compute an overall test score as well as category test scores for each defined category.

The categorization feature may be employed to partition test items by subject matter or question type. For example, a test in statistics may be divided into general concept questions and problems requiring calculations. A further subdivision in this hypothetical statistics course for problems requiring calculation might be defined for those items pertaining to central tendency statistics and those relating to measures of variability. The category scores defined above may be utilized to isolate student weaknesses in particular areas of the subject material.

By partitioning test items according to difficulty level (on a scale of 1-6) the examinee's ability can be determined. For example, a criterion condition might be the level at which the examinee scores approximately half the test items correctly.

For determination of reliability, two categories on split halves of the test can be correlated.

In addition to achievement testing, the test file system may be utilized in the administration and scoring of two-response format attitude tests, such as agree/disagree or true/false. Here, test item categorization is by the attitude being tested and one or two categories are reserved for "lie factor" items or checks for internal consistency.

```
TEST #001  COURSE NAME: DEMO AIS
11 QUESTIONS OF TYPE 2
CATEGORY DESCRIPTIONS:
1 SEQUENCING NUMBER PAIRS
2 SEQUENCING,GENERAL CONCEPT
                                ANSWER SUMMARY
NO.  CAT  ANSWER        WRONG RIGHT TOTAL A/T   B/F   C     D     E
01    1   T       00004 00002 00002 00004 00003 00001 00000 00000 00000
02    1   F       00000 00002 00002 00004 00002 00002 00000 00000 00000
03    1   T       00002 00002 00002 00004 00003 00001 00000 00000 00000
04    1   F       00000 00003 00001 00004 00003 00001 00000 00000 00000
05    1   T       00000 00002 00002 00004 00003 00000 00001 00000 00000
06    1   F       00000 00002 00002 00004 00002 00002 00000 00000 00000
07    1   F       00000 00002 00002 00004 00001 00003 00000 00000 00000
08    1   F       00000 00003 00001 00004 00002 00001 00001 00000 00000
09    1   T       00000 00002 00002 00004 00004 00000 00000 00000 00000
10    1   F       00000 00002 00002 00004 00001 00002 00000 00001 00000
11    2   D       00000 00002 00002 00004 00002 00000 00000 00002 00000
```

**Figure 5. Sample Test File**

The test files contain information about the test, i.e., the number of test items, the number of category codes and the category descriptors, and information about each test item, such as the category code and the "correct" response. In addition, an array is reserved for each test item. The CMI system utilizes this array to maintain a summary of the true/false and multiple choice responses to the item as well as the number of times an item was answered correctly. This information may be retrieved and used for item analysis, reliability checking, or determining attitude patterns for a group of examinees.

## THE COURSE DEFINITION LANGUAGE

The core of the CMI system capability lies in the course file. This file contains all the commands, communication and decision making mechanisms necessary to successfully direct a student through curriculum materials while maintaining and updating his student record and generating periodic comprehensive reports on his activities and performance. A typical sequence in a course file might be the following:

(1) Instructional materials are presented to the student, either by computer assisted instruction (CAI) at the display terminal or through some other medium assignment.

(2) Test items are administered, allowing the student to respond at his own rate.

(3) The response is evaluated and the student is provided with feedback.

(4) A decision is made in the selection of the next item or instructional alternative based on an evaluation of the student's response, past performance, background information, and the student's own preferences.

It is important to note that the CMI system itself is not adaptive; however, adaptation can be built into a course by utilizing the relationships between learner traits and past performance stored in the student record.

A course definition language, currently consisting of 25 commands, is available for course writing. A course may contain a maximum of 2,000 statements. These statements on punched cards or in card image format are compiled into a disk file and are interpreted and executed by the CMI system in an appropriate sequence for each active student. Appendix C contains sample pages from a statistics course.

The 25 course language commands fall into seven categories:

(A) Communication with the student via the display terminal, line printer and slide projector, including interrogation and evaluation of responses.

(B) Manipulation of student record items, including calculating functions of several items, updating time and achievement ratios and advancing the current lesson pointer.

(C) Decision making based on student record items or calculated functions.

(D) Key reader system commands.

(E) Testing and scoring procedures.

(F) Student progress report generation.

(G) Non-sequential command executions.

The following is a description of the available course writing language elements by category. Course command types are given with their alphabetic program equivalents in parentheses. A summary of course commands is contained in Appendix B.

A. *Communication with the Student*

The CMI system communicates with the student at the visual display terminal and keyboard. Course commands are available to clear the screen (Z), display a line of text (S), and accept a response (I). A response to an interrogation may contain from one to fifteen characters and a test and branch command (R) is available for evaluating the student's response.

The computer controlled carousel, associated with the slide screen adjacent to the display terminal, can be activated by a select slide command (P) and can also be turned off (T).

In addition, the course may direct text materials to the line printer (V). The line printer is utilized for generating lesson prescriptions or lengthy instructions for the student to retain. Other curriculum materials that do not exist in hard copy form may be generated on the line printer to avoid using the visual display terminal as a page turning device.

B. *Manipulation of Student Record Items*

Calculation of the student's current time and achievement ratios (U) may be done at any time throughout the course. [See Appendix A, (16).] The student may also be asked to record his own analysis of the difficulty of lesson material at any point in the lesson (D). The current lesson pointer may be advanced to a new lesson by the (N) command.

In addition, commands are available to set any student record item to a specific constant or to the value of another record item (F). Arithmetic functions of student record items may be calculated (Y and H) using student record SWITCH fields as accumulators. [See Appendix A, (22)]

C. *Decision-Making*

Any student record item or any calculated function in an accumulator may be tested against a specified constant, another record item or function (C). Branching is done on equal, low, and high comparison conditions.

D. *Key Reader Systems Commands*

Assignment of a student to a key reader station (K) will return control to the course, at a specified location, if that key reader station is currently in use. Otherwise, the student will be expected to key into that key reader at a future time and will be rejected at any other key reader station.

Another command (X) indicates to the CMI system that the students next action will be a key out at the visual display terminal station. This may be utilized by the course to allow the student the option of discontinuing at logical points in the curriculum.

E. *Testing and Scoring*

Two formats are available for administering test items at the visual display terminal. The first allows the test item to be displayed on the terminal screen (Q). The second assumes the student has a hard copy of the test and only the test item number is displayed (A). Both forms of test item administration accept and save the student's response.

On-line tests may be scored after all test items have been administered (M).

A student may be assigned an off-line test (O). The CMI system will expect him to return to Station #1 with a completed test answer form and feed his form into the optical mark reader for scoring.

The test results are output on the line printer for the student, recorded in his student record, and reported in his progress report file.

F. *Student Progress Report Generation*

The CMI system traces the student's activity by recording the key-in times, the time spent at each learning station, and the test results in his progress report. Additional information may be entered into the report file under course control. The course can direct text to be written onto the progress report (W). The course may also direct a student to write comments into his file (L), which may later be read by the instructor or author of the course.

G. *Non-Sequential Command Execution*

There are three statements which will cause non-sequential command execution. A "GO TO" command (G) will cause the specified statement to be executed next. The other two commands are subroutine call (J) and exit (E).

## THE STUDENT PROGRESS REPORT

One of the major functions of a CMI system is its reporting capability. The student record file, available to an instructor upon inquiry, has already been discussed previously. The student progress report, of interest to both instructor and author of the course, will be discussed below.

The progress report file is a cumulative report on all student activity on the CMI system for the day. At the termination of the CMI system operation, a computer program is activated to sort the report file and print a daily progress report for each student.

```
 STUDENT KEYED-INTO STA 00  AT 12.37 HOURS
#NAME-STATISTICS      RED                    KEYID- 0137 CSTAT AIS
#AQER-0060 AQEM-0090  AFQT-0065 TR 0.50 AR 0.75  LEVEL- 1  GOAL- 1
 STUDENT KEYED-OUT OF STA 00 AFTER 00.19 HOURS
 STUDENT KEYED-INTO STA 02  AT 12.56 HOURS
 STUDENT KEYED-OUT OF STA 02 AFTER 00.07 HOURS
 STUDENT KEYED-INTO STA 00  AT 12.63 HOURS
 STUDENT THOUGHT ORDINAL VARIABLE TO BE NOMINAL
 STUDENT THOUGHT ORDINAL VARIABLE TO BE INTERVAL.
 STUDENT THOUGHT ORDINAL VARIABLE TO BE RATIO
 DO YOU HAVE ANY COMMENTS ON THE COURSE SO FAR?
 I AM HAVING TROUBLE WITH VARIABLE CLASSIFICATION.
 STUDENT KEYED-OUT OF STA 00 AFTER 00.06 HOURS
 STUDENT KEYED-INTO STA 01  AT 12.69 HOURS
 TEST 003  070%
    CAT 1  075%  GENERAL CONCEPTS
    CAT 2  067%  VARIABLE CLASSIFICATION
 STUDENT KEYED-OUT OF STA 01 AFTER 00.05 HOURS
 STUDENT KEYED-INTO STA 00  AT 12.75 HOURS
 STUDENT DID AT LEAST 6 OUT OF 8 PROBLEMS IN LESSON 2
 TEST 004  082%
    CAT 1  050%  MEASURES OF CENTRAL TENDENCY AND VARIABILITY
    CAT 2  100%  STANDARD SCORES
    CAT 3  100%  CORRELATION
 TEST 005  054%
    CAT 1  100%  PREFERENCE FOR CAI AND VISUALS
    CAT 2  000%  NEGATIVE ATTITUDE TOWARDS MATHEMATICS
    CAT 3  100%  RELIABILITY FACTOR (50% MEANS QUESTIONABLE RELIABILITY)
 STUDENT KEYED-OUT OF STA 00 AFTER 00.39 HOURS
```

**Figure 6. Student Progress Report**

The report is headed by the initial key-in time, the student's name, key identification, and course identification. An additional line of student background information, containing three test scores (currently AQE, AQEM and AFQT scores), the student's current time and achievement ratios, his level and his goal, are also part of the report header. The body of the report contains the following information in the order of occurrence:

(a) A record of each key-in containing the key reader station identification and the time of key-in.

(b) A record of each key-in containing the station identification and the elapsed time spent there.

(c) A record for each test, administered and scored by the CMI system, containing the test identification, overall test score, and each category test score and descriptor.

(d) Any comments generated under course control. For example, "The student received three remedial treatments during lesson 2."

(e) Any comments generated by the student under course direction. For example, "Are you having any particular difficulties with the lesson so far?"
"I'm still not sure when to apply the Law of Cosines."

**Input Generation**

The CMI input files (course files, student records, and test files) are currently generated from punched cards or card image files. Interactive versions of these generation programs are currently under development. Student records and test files will be generated at the display terminal assisted by computer direction. The course file will be generated at the display terminal utilizing the printer to generate hard copy versions of the course material to reference during creation. Diagnostics will be produced for each statement after it is entered. The computer controlled slide carousel will be utilized for instruction by displaying the course command formats during the interactive creation process.

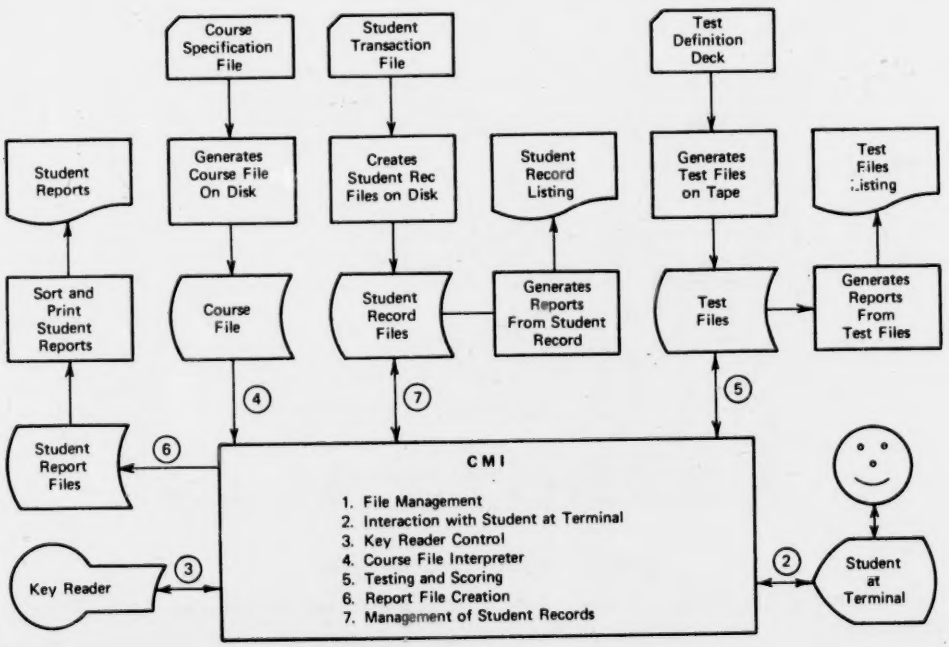


**Figure 7. CMI System Flow Diagram**

### Demonstration Courses

Two course demonstrations have been developed to date under the CMI system. The first demonstration was prepared in order to introduce the concept and some of the mechanisms of the "Advanced Instructional System" (AIS), to present examples of instructional equipment, including the operation of the key reader system, and to demonstrate the computer capabilities for monitoring and administering an instructional sequence, adapted to individual student attributes.

The second course demonstration is more content oriented. It incorporates a brief introduction and survey of methods in inferential statistics and a more advanced presentation involving the application of correlation coefficient statistics.

## INTRODUCTION TO THE ADVANCED INSTRUCTIONAL SYSTEM (AIS)

This course is partitioned into two segments. The first part briefly introduces the user (at the display terminal) to the fundamentals of the AIS. He is then directed to the sound-slide carrel to view a more comprehensive presentation of the AIS concept. If the subject is unfamiliar with the operation of the sound-slide carrel, he is given the option of three instructional media presentations:

(a) hard copy CMI system instruction manual;

(b) microfiche;

(c) computer displayed review.

When he completes his review of operating the sound-slide carrel, he may proceed to that station, key in and view the presentation.

The second segment of this course demonstrates the computerized presentation of a brief lesson adapted from the advanced organizer portion of an Inventory Management course concerning the sequencing of manufacturer's part numbers.

The user is presented at the display terminal with the descriptions of three hypothetical trainees of varying backgrounds and is asked to select one with which to identify. He is then assigned the color coded key (red, yellow, or blue) associated with the student of his choice. The computer selects one of the instructional alternative modes of presentation, based on the hypothetical trainee characteristics, and directs the user (now in the role of trainee) to his assignment. The lesson material was prepared in three formats–sound-slide presentation, programmed text, and a brief review of rules. While the user is occupied at his assigned learning station, a second, and then a third, subject may select one of the remaining trainee keys, key in at the visual display terminal, and receive the appropriate lesson assignment. When one of the subjects completes his assignment, he returns to the display terminal where he is given the option of receiving an on-line or off-line test on the material just learned. The CMI system scores and evaluates the test and offers remedial instruction accordingly. Upon completion of the lesson, the subject may key in as a different hypothetical student if he wishes to see how another student would be directed.

## STATISTICS COURSE DEMONSTRATION

The development of the statistics course was prompted by a desire for a content oriented course that could demonstrate the computer controlled slide carousel. Statistics was chosen as the subject because it could be utilized as introductory curriculum material for instructor personnel as well as for employment in demonstrations.

The statistics package includes two distinct courses. The first course consists of introductory material emphasizing basic concepts in methods of inferential statistics. Although the curriculum material is directed toward a rather homogeneous group of students (i.e., college level with some experience in statistical methods), an objective of the course is to attempt to discriminate among the student population by developing a student profile as a function of relevant aptitude test scores, performance in the course, and an attitude test* to determine the trainee's preference for CAI and visuals and the extent of any negative attitudes towards mathematics.

The curriculum material is partitioned into four lessons:

(1) Basic definitions.

(2) Organization of data and graphic characteristics of frequency distributions.

(3) Measures of central tendency and dispersion.

(4) Standard scores, correlation, reliability, and validity.

Lesson (1) offers a review of some basic definitions covering population, sampling theory, variable classification, and the semantics of summation notation. The trainee may request a hard copy form of particular material which will be generated on the line printer for his review and future reference. The student is asked several review questions and receives remedial treatment upon incorrect responses. At the end of the lesson, the student is directed to take an off-line test. The test score results are an indication of the extent to which the student still needs to review these basic definitions and forms a part of the performance measurement for his profile.

In lessons (2), (3), and (4), the material is interactively presented at the visual display terminal in conjunction with prepared slide illustrations. Questions are asked frequently and remediation administered. At the termination of the course, the final test examination and the attitude test are administered.

The student's record file and progress report are available for evaluation at the completion of the course. The student's own evaluation of the curriculum material is contained in his progress report.

The second segment in the statistics curriculum package is a correlation statistic enquiry system. It is not a course in the usual sense, that is, the trainee is never tested or evaluated on his performance. It serves as a review of correlation statistics by instructing a trainee in which statistic to use as a function of his data. Data is characterized by variable level, as parametric or non-parametric, and as continuous or dichotomous. (All of these data classifications are reviewed for the trainee if needed.) The trainee makes his enquiries at the visual display terminal and the enquiry response is presented on the slide screen.

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* The attitude test is unvalidated and serves mainly as a demonstration of the potential capabilities of a CMI system.

## CONCLUSION

In conclusion, the work effected under this contract accomplished the following:

(1) The design and implementation of a small scale computer managed instructional system facilitating experimentation with basic CMI system features and curriculum materials.

(2) Experimentation with a hardware configuration utilizing a key reader system, a marked card reader, visual display terminal, and slide carousel, all controlled by computer and auxiliary off-line learning resources such as the sound-slide carrel and the microfiche reader.

(3) The development of two course material presentations under the designed CMI system software—the first in order to introduce the Advanced Instructional System and demonstrate the mechanisms of CMI; the second to present and experiment with curriculum material in methods of inferential statistics.

## APPENDIX

### A. Detailed Summary of Student Record Items

The following discussion of the student record utilizes each of the record item types (1-22) to specify the system input and capability. A print-out of a student record file is contained in Figure 4.

A. *Student Identification*

(1) STUDENT NAME includes last and first names and middle initial. The CMI system always addresses the student by his first name. However, for the purpose of accurate identification, the student progress report is headed by his entire name as well as his key code.

(2) KEY CODE is used by the CMI system to associate the appropriate student record with the active student keying in at a learning station.

B. *Student Background*

(3) CURRENT LEVEL is a numerical field which may be assigned any meaningful code. It may be tested during a course and utilized for curriculum branching strategies.

(4) GOAL is the level the student wishes to attain. This parameter reflects the extent to which different instructional objectives may be recognized for different students. It may be utilized in the same manner as item (3).

(5) NUMBER OF PREVIOUS COURSES TAKEN is an aspect of the student's previous experience with this CMI system. His performace in a course may be contingent upon his familiarity with the system's operations.

(6) LAST THREE CMI COURSES TAKEN appear in the student record for further prerequisite history.

(7) There are six fields available for holding input data such as aptitude and attitude test scores or other psychological indices pertinent to selecting appropriate branching strategies in the assignment of instructional alternatives within the curriculum. For example, trait anxiety, response latency patterns or pretest scores might be relevant to the decision making processes of a course. These fields are currently used to retain the AFQT, general, AQEM, AQEE and AQEA aptitude scores and one attitude test score.

C. *Curriculum-Associated Data*

(8) COURSE NAME is used to fetch the appropriate course (from the disk) when an active student keys into a learning station.

(9) A performance model for the course is contained in the form of PERFORMACE TIMES and ACHIEVEMENT TEST SCORES for each lesson module. This model may be that of an average student, of an "expert" or advanced student, or perhaps a minimum performance criterion in the course. The CMI system computes a time and achievement ratio of the student's performance relative to the model. These ratios are an aspect of the student's profile within the course and are utilized by the CMI to indicate student progress, to reflect the need for remedial procedures and to project completion times.

(10) TOTAL NUMBER OF LESSONS IN THE COURSE is used in conjunction with item (11), CURRENT LESSON NUMBER, to give broad indication of the student's status in the course.

D. *Dynamic Record Keeping*

(11) CURRENT LESSON NUMBER indicates the student's current status in the course. It is utilized by the CMI system when storing specific lesson associated information (such as test scores, time accounts, instructional media, and dates) in the student record.

(12) NEXT SEQUENTIAL COURSE COMMAND indicates the exact location of the student within the curriculum.

(13) COURSE STATUS reflects whether or not the student has started a course and if his termination in the course is satisfactory. The field is output upon inquiry into the student's record.

(14) ASSIGNED STATION is the key reader identification code for the student's current off-line assignment.

(15) TEST NUMBER is the identification for the currently assigned test and is used to fetch the appropriate test file when a student inputs his test answer form at the optical reader station.

(16) TIME and ACHIEVEMENT RATIOS are computed and updated, under curriculum control, utilizing the performance model input data for the course. [See item (9).]

(17) ERROR MESSAGE CODE retains a record of the student key-in at an unassigned station, so that he may be redirected to the correct station.

E. *Lesson-Associated Information*

The following learning parameters appear for each of the eight available lesson modules in the course:

(18) A critical parameter of learning is the rate at which the student moves through the course material. This is recorded for each lesson by three items. The START DATE and FINISH DATE indicate the broad passage of time underlying the lesson module assignment. The ELAPSED TIME, recorded in hundredths of an hour, accounts for the time that the student is actively involved with the curriculum material. The elapsed time accounting mechanism can also be utilized to obtain response latencies, which are retained in unused portions of the student record.

(19) MEDIA CODE is a record of the instructional medium, assigned to a lesson. The coding is as follows:

1 = CAI (computer assisted instruction)
2 = reading assignment
3 = sound-slide
4 = film
5 = microfiche
6 = laboratory assignment

(20) DIFFICULTY INDEX retains the user's rating of his difficulty with the lesson module. The student rates the lesson difficulty on a scale of 1 to 5 (with 5 being most difficult). This type of input facilitates decision making processes under the student's

control regarding the curriculum. Furthermore, this information is accessible to the instructor and author of the course.

(21) When instruction is individualized, testing must be done frequently and at different times for each student. The computer decides, under curriculum control, when a student is ready to be tested and which test to assign. There are seven available fields (per lesson) to retain these TEST SCORES. These fields may be utilized to store an overall score and six "category scores" on a single test or to hold test scores from several tests.

F. *Additional Fields in the Student Record*

(22) There are three "SWITCH" fields available in the student record that may be accessed and utilized by a CMI course. For example, they may be used as accumulators to compute complex functions of the various learning paramters for the purpose of branching strategy. They may be used as counters to record the number of student "retries" for success at a given task or simply to remember information that needs to be recalled at some future point in the curriculum.

B. **Summary of Course File Commands**

| CODE | DESCRIPTION |
|---|---|
| A | Accept an answer to printed test questions on line |
| C | Compare student record item(s) and branch |
| D | Ask student to rate lesson difficulty |
| E | Exit subroutine |
| F | Set value of a student record item |
| G | GO TO |
| H | Add/Subtract two student record items |
| I | Interrogate student and wait for response |
| J | Call Subroutine |
| K | Assign student to station and check if station busy |
| L | Ask student to write comment in his report file |
| M | Score test, store and print result |
| N | Advance current lesson pointer |
| O | Off-line test to be scored at optical reader |
| P | Select and display a slide |
| Q | Ask test question and accept answer on-line |
| R | Test response and branch |
| S | Display a statement (VTØ5) |
| T | Turn On/Off slide projector |
| U | Update time and achievement ratio |
| V | Print a line of text |
| W | Write a comment to student report file |
| X | Student logging off system |
| Y | Add/Subtract a value to student record items |
| Z | Clear screen, home cursor |

C. **Sample from a Course File**

Below are two sample pages from the introductory statistics course described previously in this report. The following discussion will consist of explanatory notes associated with the circled numbers appearing on the sample pages:

(1) (2) (3) The header line consists of the course file name (1), number of lessons (2) and course descriptor (3).

(4) This is the performance model (hours and grades for each lesson) prescribed for this course.

(5) This is the label field of the first statement which is always 0001. This column, labelled "SEQ NO" refers to the sequential order in which the statements appear on the disk file.

(6) This is the command code field of the first statement. "Z" clears the visual display terminal screen and positions the cursor in the upper left hand corner.

(7) These commands set the value of the "SWITCH" fields in the student record file to zero.

(8) These commands communicate the verbal data (to the right) on the visual display terminal screen.

(9) The "I" command displays the qustion or instruction, requesting a response.

(10) These "R" commands are looking for a response of "A" or "B" (11) to the interrogation in statement 1363 (9).

(12) and (13) These are the branch to statement labels for equal and unequal conditions respectively.

(14) This is a slide select statement. This statement selects slide 001.

(15) This is a subroutine call. The subroutine is contained in statements 0025 through 0031.

(16) This is the subroutine exit statement.

(17) Tests if key reader station 02 is free. If it is free, the subject will be given his assignment there.

(18) This statement causes the computer controlled slide projector to be turned off.

(19) The "X" command allows the subject to log off (key out) from the visual display terminal key reader. He will be expected to resume the curriculum at statement 1450 when he returns.

(20) The subject is allowed to write a comment into his progress report.

(21) The student is requested to evaluate the difficulty of this lesson on a scale of 1 through 5.

(22) The student is assigned test #003 to be taken off-line.

(23) A set of definitions are directed to the line printer for the student's reference.

```
CSTAT AIS 5 INSTRUCTIONAL MANAGEMENT STATISTICS
 AVG FOR LESSON1 LESSON2 LESSON3 LESSON4 LESSON5 LESSON6 LESSON7 LESSON8
 HOURS     0025    0013    0015    0020    0000
 GRADES    0070    0065    0000    0075    0000

SEQ       TYPE    ITEM NAME AND VALUE,STATEMENT,QUESTION,
NO.  NSCN   NDIF NNNI          RESPONSE, AND/OR COMMENT

0001        Z
1367        F
1368        F
1369        F
1360        S
1361        S
1362        S
1363        I
1364 1366   R 1365      A
1365 1100   R 1363      B
1366        Z
0068        P           001
0032        S           MEASUREMENT AND EVALUATION WHICH INVOLVE THE ASSIGNING OF
0033        S           NUMBERS TO OBSERVED DATA AND THE INTERPRETATION OF THOSE
0034        S           NUMBERS, ARE COMING MORE AND MORE TO DEPEND ON STATISTI-
0035        S           CAL PROCEDURES. NEARLY ALL OF TODAYS TEST MANUALS REFER
0036        S           TO    . CENTRAL TENDENCY
0037        S                 . VARIABILITY
0038        S                 . PERCENTILES AND PERCENTILE RANKS
0039        S                 . STANDARD SCORES
0010        S                 . RELIABILITY
0011        S                 . VALIDITY
0012        S           THIS COURSE WILL TRY TO SERVE AS AN INTRODUCTION TO
0013        S           STATISTICS, BY OMITTING MORE ADVANCED MATERIALS IN ITS
0014        S           SURVEY, AND BY EMPHASIZING CONCEPTS MORE THAN COMPUTATION
1900        S           IN ADDITION, THE DATA ACCUMULATED IN YOUR STUDENT
1901        S           RECORD FILE WILL BE USED TO GENERATE A PROFILE TO
1902        S           TO FACILITATE THE SELECTION OF INSTRUCTIONAL MAT-
1903        S           ERIALS, PARTICULARLY SUITED TO YOUR NEEDS AND
1904        I           ABILITIES.   (TYPE CR TO CONTINUE)
1770        Z
1771        I           TYPE "B1" TO BYPASS LESSON 1;OTHERWISE TYPE CR.
1772 0461   R 0015      B1
0015        Z
0016        S           REMEMBER, WHEN YOU TYPE A RESPONSE, YOU MUST HIT CARRIAGE
0017        S           RETURN (THE CR KEY) TO TERMINATE YOUR ANSWER. ANY ERROR
0018        S           IN TYPING MAY BE ERASED PRIOR TO CARRIAGE RETURN BY
0019        S           PRESSING THE RUBOUT KEY TO BACK-UP. WHEN YOU HAVE FIN-
0020        S           ISHED READING THE SCREEN, PRESS THE CR KEY TO CONTINUE.
0021        I           FOR EXAMPLE, YOU MAY PRESS  CR  NOW.
0022        Z
0023 1440   I           WE WILL START OFF WITH A DEFINITION OF TERMS,READY ?
1440        S           GOOD. THE DEFINITIONS THAT YOU WISH TO REVIEW WILL BE
1441        S           GENERATED ON THE LINE PRINTER SO THAT YOU MAY STUDY THEM
1442        S           AND RETAIN A COPY FOR FUTURE REFERENCE. HERE IS THE LIST.
1443        S
1444 0025   J 0033        -----CALL DEF. LIST------
0024        Z
0025        S             (A) ALL OF THE BELOW
0026        S             (B) POPULATION, FINITE AND INFINITE
```

```
0027       S          (C) SAMPLING, ESTIMATE, PARAMETER
0028       S          (D)VARIABLE CLASSIFICATION=ORDINAL,NOMINAL,INTERVAL,RATIO
0029       S          (E)SUMMATION NOTATION
0030       S          (F)NONE OF THE ABOVE
(14)0031   E
0032 0024  J 0033                  ----- CALL DEFINITION LIST-----
0033       I          SELECT THE LETTER FOR WHAT YOU WISH TO SEE NEXT.
0034 0040  H 0035     A
0035 0057  R 0036     B
0036 0060  R 0037     C
0037 0062  R 0038     D
0038 0064  R 0039     E
0039 1445  R 0033     F
0040 0100  J 0041                  (A) RTE-CALL POP DEF
0041       G
0042 0150  J 0043                        CALL SAMPLE DEF
0043 0195  J 0044                        CALL VAR. DEF
0044 0370  J 1453                        CALL SUMMATION NOT.
1445       I          HAVE YOU GENERATED ANY DEFINITIONS ON THE LINE PRINTER?
1447 1453  R 1448     YES
1448 1450  R 1449     NO
1449 1447  I          ANSWER YES OR NO.
1450       I          HERE ARE SOME QUESTIONS. ARE YOU READY?
1451 0125  J 1452         ---POP. DEF. Q----
1452 0270  J 0045         ---VAR. CLASS. Q-----
1453       S          ALRIGHT. TAKE YOUR DEFINITIONS FROM THE LINE PRINTER
1454       S          TO READING CARREL #2. KEY IN AND REVIEW THEM.
1455       S          RETURN HERE WHEN YOU ARE READY TO CONTINUE.
(17)1456   K 1456     02
1457       S          YOU MAY KEY OUT NOW.
(18)1458   T          OFF
(19)1459 1450 X
0045       Z             -----END OF LESSON 1--------
0046       S          THIS COMPLETES LESSON 1 OF THIS COURSE. YOU WILL NOW BE
0047       S          TESTED. AFTER KEYING OUT OF THIS STATION, TAKE TEST #003
0048       S          FROM THE TEST FILE. MARK YOUR ANSWERS ON A BLANK ANSWER
0049       S          CARD. THEN KEY IN AT STATION 01 AND INPUT YOUR ANSWERS AT
0050       S          THE OPTICAL READER. KEY BACK IN HERE WHEN YOU ARE DONE.
(20)0051   L          DO YOU HAVE ANY COMMENTS ON THE COURSE SO FAR?
(21)0052   D
(22)0053   D          003
0054       S          YOU MAY KEY OUT NOW.
1460       T          OFF
0056 0461  X
0057       G                    -----STUDENT SELECTED (B)
0058 0100  J 0032                     CALL POP DEF
0060       G                    -----STUD. SELECTED (C)
0061 0150  J 0032                     CALL SAMPLE DEF - RETURN TO SELECT
0062       G                    -----STUD  SELECTED (D)
0063 0195  J 0032                     CALL VAR DEF - RETURN TO SELECT
0064       G                    -----STUD  SELECTED (E)
0065 0370  J 0032                     CALL SUMMATION NOTATION
0082       I          WOULD YOU LIKE TO GO BACK AND REVIEW SOME DEFINITIONS?
0083 0032  K 0084     YES                   GO TO SELECT
0084 0046  K 0082     NO                    TAKE TEST
(23)0100   V          ------DEFINITION OF TERMS --------
0101       V          STATISTICS IS A BRANCH OF SCIENTIFIC METHODOLOGY, DEALING
0102       V          WITH THE COLLECTION, CLASSIFICATION, DESCRIPTION, AND
```

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Further information on this system can be obtained from the following source:

(1) Espeland, L.R., & Walker, G.S. *An experimental CMI system on the PDP 11/20*. Paper presented at Digital Equipment Computer Users Society Symposium, Philadelphia, 2-5 May 1973.